

Suitability of Extraction Systems with Macrocyclic Ligands for the Study of Rutherfordium

3. Kinetics of Zr and Hf Extraction with Dibenzo-18-crown-6 and Dicyclohexano-18-crown-6

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In two contributions to last year's annual report we described the use of dibenzo-18-crown-6 (DB18C6) and dicyclohexano-18-crown-6 (DC18C6) as potential extractants for the study of rutherfordium [1]. To test the suitability of the system, we studied the extraction of zirconium and hafnium from hydrochloric acid using these crown ethers. It was found that the extraction yield rises for both elements with increasing acid concentration and increasing concentration of extractant. Suitable conditions for the separation of Zr from Hf could be found for both crown ethers studied. This is the first step in finding an extraction system that can be used to determine whether Rf shows a behavior more similar to Zr or Hf.

Another important factor in developing a suitable extraction system for chemistry experiments with transactinide elements is the kinetics of the reaction. To ensure that a chemical system can be used for the study of rutherfordium, the kinetics of the reaction need to be fast. The system has to reach equilibrium in a short time, otherwise it cannot be used for the study of short-lived isotopes. In this work we studied the kinetics of the extraction with DB18C6 and DC18C6 by determining the extraction yield as a function of contact time between the two phases. For this purpose the mixing time was varied between 10 and 60 seconds, while the time for centrifugation was kept constant. The goal of these experiments was to ensure that the extraction reaches equilibrium on a time scale short enough to allow for the study of rutherfordium.

The experiments were performed at the 88-Inch Cyclotron at LBNL using the short-lived isotopes ⁸⁵Zr ($T_{1/2} = 7.9$ m) and ¹⁶⁹Hf ($T_{1/2} = 3.25$ m). The isotopes were produced by bombarding a ^{nat}Ge with a 83.6-MeV ¹⁸O⁴⁺ beam and a ¹²⁴Sn target with a 228.0-MeV ⁵⁰Ti¹¹⁺ beam, respectively. The two beams were delivered by the cyclotron as a cocktail beam [2].

The zirconium and hafnium isotopes produced were separated from the beam and interfering reaction products using the Berkeley Gas-filled Separator (BGS). After traveling through the BGS, the products passed through a 3.3- μ m Mylar window into the Recoil Transfer Chamber (RTC) [3]. The Hf recoil products were degraded by passing through a 5.7- μ m Mylar foil before entering the RTC window to ensure that they were completely stopped inside the RTC. Inside the RTC, the recoils were thermalized in helium and transported to the chemistry setup using a potassium chloride aerosol gas-jet. The gas-jet was operated with an average flow rate of 1.8 L/min and a pressure of 1.2 bar.

The aerosol particles containing the radionuclides were transported over a distance of ~20 m and deposited on plati-

num foils. The aerosol residue was dissolved in 100 μ L of 10 M HCl and transferred to a centrifuge cone containing an additional 3900 μ L of the same acid. The aqueous phase was mixed with an equal volume of crown ether diluted in dichloromethane. Phases were vigorously mixed between 10 and 60 seconds and centrifuged for 20 seconds. Afterwards a 3-mL aliquot was taken from each phase and assayed using a HPGe γ -ray detector.

Figure 1 shows a plot of the extraction yield versus mixing time for the extraction of Zr and Hf with 0.090 M DB18C6 and 0.025 M DC18C6 from 10.0 M HCl. The results show that for both elements and both crown ethers the extraction yield does not change significantly if the mixing time is decreased from 60 to 10 seconds. The complex formation and extraction is already completed after 10 seconds. This means the extraction systems are fast enough for the study of rutherfordium.

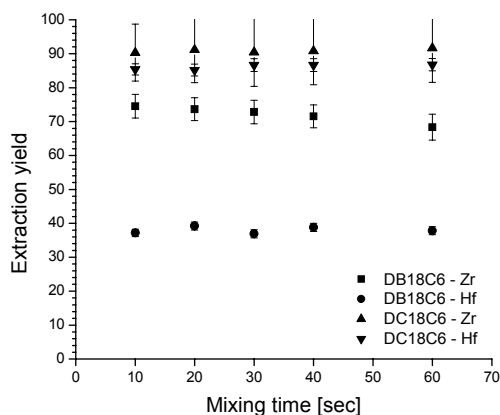


FIG. 1: Extraction yields for Zr and Hf extraction from 10.0 M HCl into 0.090 M dibenzo-18-crown-6 (DB18C6) and into 0.025 M dicyclohexano-18-crown-6 (DC18C6) as a function of mixing time.

REFERENCES

- [1] R. Sudowe *et al.*, Annual Report, Nuclear Science Division, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA, USA (2004), LBNL-55057.
- [2] D. Leitner *et al.*, Proc. 15th Int. Workshop on ECR Ion Sources, ECRIS '02, Jyväskylä, June 12-14, 2002 and LBNL-51451 (2002)
- [3] U. W. Kirbach *et al.*, Nucl. Instrum. Meth. A **484**, 587 (2002)